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*The Proposed Fissile-
Material Production
Cutoff*

Next Steps

*Brian G. Chow, Richard H. Speier,
Gregory S. Jones*

*Prepared for the
Office of the Secretary of Defense*

**National Defense
Research Institute**

19960228 072

This research described in this report was sponsored by the Office of the Secretary of Defense under RAND's National Defense Research Institute, a federally funded research and development center supported by the Office of the Secretary of Defense, the Joint Staff, and the defense agencies, Contract No. MDA903-90-C-0004.

Library of Congress Cataloging in Publication Data

Chow, Brian G.

The proposed fissile-material production cutoff : next steps /
Brian G. Chow, Richard Speier, Gregory S. Jones.

p. cm

"Prepared for the Office of the Secretary of Defense."

"MR-586-1-OSD."

ISBN 0-8330-2359-4

I. Nuclear nonproliferation. 2. Nuclear disarmament—
United States. I. Speier, Richard. II. Jones, Gregory S.
III. United States. Dept. of Defense. Office of the Secretary of
Defense. IV. Title.

JX1974.73.C49 1995

327.1 '74—dc20

95-12856

CIP

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Published 1995 by RAND

1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138

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.008. la960205s1995 caua 000 0 eng d
.010. la95012856
.020. la0833023594
.027. laRAND/MR-586-1-OSD
.037. lalc\$15.00
.040. laCStmoRlcCStmoR
.043. lan-us---
.050. 00laJX1974.73lb.C49 1995
.100. 1 laChow, Brian,ld1941-lw
.245. 14laThe proposed fissile-material production cutoff :lbnext steps /
lbBrian G. Chow, Richard H. Speier, Gregory S. Jones.
.260. laSanta Monica, CA :lbRAND,lc1995.
.300. laxv, 51 p. :lbill. ;lc23 cm.
.500. la"National Defense Research Institute."
.504. laIncludes bibliographical references.
.506. 1 laUNCLASSIFIED
.520. laPresident Clinton has announced that the United States will take
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proposes some "next steps" to the proposed convention, to further
strengthen worldwide control of weapon-usable material. These next steps
would have two main objectives. The first would be to reduce or to
transfer to secure custody current plutonium and highly enriched uranium
stockpiles. The second would be to prohibit or to restrict to fewer
locations the production of these materials. The report also analyzes the
political and economic obstacles that might hinder negotiation of these
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The U.S. proposal is described first, then the report quantifies various
countries' inventories and ability to produce weapon-usable material.
.536. laOffice of Secretary of Defense;lbMDA903-90-C-0004;ldRCN 470R
.580. laSupersedes RAND/MR-586-OSD.
.650. 0laNuclear nonproliferation.
.650. 0laNuclear disarmamentlzUnited States.
.695. 1 laNuclear proliferation.
.695. 2 laDisarmament.
.700. 1 laSpeier, Richard H.
.700. 1 laJones, Gregory S.lw
.710. 2 laNational Defense Research Institute (RAND Corporation).
lbInternational Security and Defense Policy Center.
.710. 1 laUnited States.lbDept. of Defense.lbOffice of the Secretary of
Defense.lw
.787. laIRRAND/MR-586-OSD
.980. laDefense and Technology Planning
.981. laNational Security Research
.982. la3
.983. laMILITARY STRATEGY AND TACTICS
.984. la19960131;lb19960131
.986. la19960131
.991. laInternational Security and Defense Policy Center
.992. la9601
.596. la1 2 3

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PREFACE

In September 1993, President Clinton announced that the United States will take a comprehensive approach to the growing global accumulation of fissile material. As an element of that approach, he proposed a multilateral convention banning the production of such material for nuclear-explosives purposes or outside international safeguards.

We examine and recommend next steps to the proposed convention. These negotiating steps or options are to further strengthen the worldwide control of weapon-usable material. In addition, we analyze the political and economic obstacles that might hinder the negotiation of the recommended next steps, and suggest measures that would mitigate these obstacles.

To study and recommend the next steps and measures, we first describe the U.S. proposal, quantify various countries' inventories and ability to produce weapon-usable material, and determine what remains to be done beyond the proposed convention. These preliminary but necessary analyses then lead us to the main part of this report, where we describe possible next steps, identify potential obstacles to these steps, and then suggest measures to mitigate opposition to them. Those who are familiar with the proposed convention might skip Chapter Two on the U.S. proposal.

The project was conducted under the International Security and Defense Policy Center of RAND's National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, and the defense agencies.

The views expressed in this report are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. government.

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SUMMARY

Nuclear nonproliferation has long been a principal security objective of the United States and most other countries. The nuclear nonproliferation treaty (NPT), which took effect in 1970, sought to limit nuclear weapons to the countries that then possessed them (the United States, the Soviet Union, the United Kingdom, France, and China). It is widely believed that, since then, several other states (India, Israel, Pakistan, and North Korea) have acquired nuclear weapons. One objective of current nonproliferation policy is to cap and eventually reverse the nuclear-weapon programs in these undeclared nuclear-weapon states. Another is to prevent terrorist and other subnational groups from gaining access to nuclear weapons or to sensitive nuclear materials, i.e., plutonium or highly enriched uranium (HEU). Such materials are produced in military and some civilian nuclear programs.

To help achieve these objectives, President Clinton outlined in September 1993 a "framework for U.S. efforts to prevent the proliferation of weapons of mass destruction." This framework included a proposed multilateral convention prohibiting the production of plutonium or HEU unless it is for purposes other than nuclear-weapon production and then only if it is done under international safeguards. The United Nations General Assembly endorsed the proposal within three months subject to the important change that the convention be "nondiscriminatory," that is, that it apply to declared and undeclared nuclear-weapon states and nonnuclear-weapon states alike.

What will be the effect of such a convention on the future availability of plutonium and HEU? Can additional steps reduce the opportuni-

ties for nuclear-weapon proliferation? What might be done to gain the international community's acceptance of further steps? In the research reported here, we have attempted to answer these questions.

AVAILABILITY OF SENSITIVE NUCLEAR MATERIALS

To assess the effects of the proposed convention, we began by analyzing the current and near-future global availability of plutonium and HEU. We evaluated available data to determine countries' stocks of and ability to produce HEU and weapon- and reactor-grade plutonium (all of which can be used in weapons) and divided these amounts by that necessary to make crude atomic bombs. We carried out this analysis for undeclared nuclear-weapon states (named above) and nonnuclear-weapon states that once had an interest in nuclear-weapon development and have the ability to resume a weapon program (Argentina, Brazil, and South Africa). We found that these seven countries combined can now or will soon be able to produce enough sensitive nuclear material to manufacture about 230 bombs per year. This is in addition to a combined accumulated stockpile large enough to support the manufacture of about 220 bombs. (Seventy percent of this stockpile is in India and Israel.)

Some insight into the potential availability of sensitive nuclear materials can be gained by considering the separated plutonium being generated in countries with large reprocessing plants (France, the United Kingdom, Russia, and Japan). This plutonium is intended to be used in the nuclear fuel cycle, which will involve transfers between holding points including transfers to other countries. It is from these transfers and holding points that nations or subnational groups might divert or seize some of the material. We estimate the amount of plutonium in the cycle at any given time to be equal to the amount that the system can produce in a year. Combined, these states process enough plutonium annually to make approximately 4,400 atomic bombs; this number will grow to 5,600 within a decade. Thus, the diversion or seizure of even a tiny fraction of this material would be enough to make several bombs.

EFFECTS OF THE PROPOSED CONVENTION

What effect would the proposed convention limiting HEU and plutonium production have? First, although the convention does not deal with existing military stockpiles, it would put plutonium and HEU produced in the future in non-NPT states such as India, Pakistan, and Israel under full-scope international safeguards. This would have some of the effect of the NPT in that implementation of safeguards would deter the diversion of this plutonium and HEU for weapon purposes, and abrogation of the convention would afford some warning that weapons were being manufactured using this material.

Second, the proposed convention would require that nuclear-weapon states stop producing plutonium and HEU for weapon purposes. China would be most affected by this requirement, because it is the only nuclear-weapon state that may still be producing weapon-related plutonium. The other nuclear-weapon states no longer produce plutonium for weapons, and none produces HEU for weapons. However, the convention will formally commit them not to produce plutonium or HEU for weapons in the future.

The convention would thus increase the moral, legal, and to some extent, practical constraints on the production of nuclear weapons by non-NPT states, and it could decrease plutonium production by nuclear-weapon states. However, the question of how much potential for bomb-making would remain is still to be addressed. Our analysis shows why the proposed convention is only one element in President Clinton's nonproliferation framework.

The convention would leave in place existing stocks of plutonium and HEU accumulated for weapon-related purposes. There is also a residual risk associated with further production and stockpile accumulation carried out for nonweapon purposes—activities that would be allowed under the new convention (with safeguards). Parties to the new treaty could clandestinely build facilities to convert stored plutonium, which would probably be in oxide form, into the metal form needed for bombs, while simultaneously constructing the non-nuclear components of the weapons. Their efforts might not be detected until the oxide was withdrawn from the storage site (in violation of safeguards). It might be only a matter of days or weeks from

that event until nuclear weapons were completed. And, with large flows of civilian fuel-cycle plutonium remaining, the threat of theft, as described above, remains .

POSSIBLE FURTHER STEPS

Having established that there will be a residual availability of plutonium and HEU for weapon manufacture after the implementation of the proposed convention, we considered two further steps as a means to reduce that availability. First, current plutonium and HEU stockpiles (both safeguarded and unsafeguarded) might be reduced or transferred to secure custody, and, second, the production of these materials for any purpose might be abandoned or restricted to fewer locations.

Reducing stockpiles should reduce the number of bombs that could be made. This would be a valuable step but not by itself sufficient. Even if excess stocks are eliminated, substantial plutonium would still be present at any given time in the civilian fuel cycles of countries with reactors using plutonium. Also, any nonnuclear nation interested in building nuclear weapons could provide itself with a plutonium stockpile by establishing a plutonium-based civilian fuel cycle.

Elimination of plutonium production for any purpose, on the other hand, should have a very large effect on its availability for weapon manufacture. If stockpiles were also eliminated, nonnuclear-weapon states would have nothing to seize and convert to bombs and subnational groups would have nothing steal. Nations such as Japan, France, and the United Kingdom, which are trying to establish a plutonium-based civilian fuel cycle as a hedge against exhaustion of uranium supplies, would be against a complete production cutoff. Consequently, the U.S. government, understandably reluctant to cross its allies, has declined to propose such a cutoff. However, because the economics of and political support for the civilian use of plutonium have been steadily deteriorating, various measures might be implemented to allay plutonium producers' concerns:

- Press the logic that plutonium stock disposition and a total cutoff or severe restriction on plutonium production will be necessary for effective control.

- Point to the U.S. example—the abandonment of civilian uses of plutonium—and add other examples, e.g., Germany. Also point to regional opponents of such programs, e.g., North and South Korea, and China with respect to Japan's program and perhaps Israel with respect to its neighbors' programs.
- As the number of holdouts is reduced, press harder on the remaining plutonium advocates.
- Initiate international efforts to improve the alternatives to plutonium use, including fuel-efficiency improvements in existing and advanced once-through low-enriched or natural uranium-based nuclear reactors and to identify additional uranium resources.
- Suggest the stockpiling of natural and low-enriched uranium fuel as a more immediate and proliferation-resistant energy security measure than plutonium fuel cycles.
- Suggest a progression of increasingly restrictive steps, beginning, for example, with a ban on new construction of plutonium facilities.
- Take actions to minimize the losses suffered by organizations currently profiting from plutonium activities.
- Cut off the production of "civilian" weapon-usable material first and use existing stockpiles to support sensitive activities that require time to phase out.
- Suggest a renewable moratorium on plutonium production.

CONCLUSION

If the proposed convention is supplemented by stockpile reduction or elimination and by severe restriction or total cutoff of plutonium and HEU production for any purpose, the danger of proliferation will be greatly reduced. The measures listed above might be taken to mitigate any negative effects such additional steps would have on some countries and thus improve the negotiating environment for further action.

We recommend that the United States at a minimum not foreclose, significantly delay, or deemphasize the possibility of further action to substantially reduce the availability of plutonium and HEU. It is im-

portant that the world perceive a U.S. position along the following lines:

- No nation should assume that the proposed convention offers an entitlement to activities it does not prevent. Otherwise, it may be difficult in the future to convince countries to abandon civilian plutonium fuel programs if they have made additional large investments in such programs under the auspices of the new treaty. To prevent such an eventuality, everyone must understand the limits at the outset.
- Negotiations over the proposed convention will be the first step, to be followed by or, better, accompanied by negotiations over a broader plan to cut off plutonium production and over stockpile disposition. Concurrent negotiations are better than sequential ones, given the length of time involved.

ACKNOWLEDGMENTS

We thank our colleagues, Arnold Kanter, Bruno Augenstein, and Paul Davis, for reviewing this report and offering many valuable comments. However, this does not imply that they agree with us on all aspects of our assessments and recommendations.

Nuclear nonproliferation has long been a principal security objective of the United States and most other countries. The nuclear nonproliferation treaty (NPT), which took effect in 1970, sought to limit nuclear weapons to the countries that then possessed them (the United States, the Soviet Union, the United Kingdom, France, and China). It is widely believed that, since then, several other states (India, Israel, Pakistan, and North Korea) have acquired nuclear weapons. One objective of current nonproliferation policy is to cap and eventually reverse the nuclear-weapon programs in these undeclared nuclear-weapon states. Another is to prevent terrorist and other subnational groups from gaining access to nuclear weapons or to sensitive nuclear materials, i.e., plutonium or highly enriched uranium (HEU). Such materials are produced in military and some civilian nuclear programs.

To help achieve these objectives, President Clinton outlined in September 1993 a "framework for U.S. efforts to prevent the proliferation of weapons of mass destruction." This framework included a proposed multilateral convention prohibiting the production of plutonium or HEU unless it is for purposes other than nuclear-weapon production and then only if it is done under international safeguards. The United Nations General Assembly endorsed the proposal within three months subject to the important change that the convention be "nondiscriminatory," that is, that it apply to declared and undeclared nuclear-weapon states and nonnuclear-weapon states alike.

What will be the effect of such a convention on the future availability of plutonium and HEU? Can additional steps reduce the opportuni-

ties for nuclear-weapon proliferation? What might be done to gain the international community's acceptance of further steps? In this report, we propose some answers to these questions.

The report is structured as follows. Chapter Two describes the U.S. proposal. Chapter Three quantifies inventories and production capabilities of weapon-usable material in various countries. These data are then used in Chapter Four to analyze the effect on proliferation of a proposed cutoff and in Chapter Five to develop other approaches to supplement the proposed convention. In Chapters Four and Five, we also estimate the time that would be required to negotiate the proposed convention and the implications of this time for the phasing of next steps. Chapter Five discusses steps beyond the current proposal, the potential obstacles to negotiating these steps, and means to mitigate these obstacles. We also present our recommendations on next steps and mitigating measures in Chapter Five. Finally, our conclusions are given in Chapter Six.

This report focuses on access to potential nuclear weapons as the key criterion for comparing alternatives. It does not look at many other issues—for example, verification, the interaction of a cutoff with the renewal of the NPT, and various legal and drafting issues. By choosing to exclude these issues at this time, we are better able to focus on the main issue of accessibility to potential weapons and thus to see clearly the essential strengths and weaknesses of the alternatives and to decide which alternative or combination of them should be pursued.

THE U.S. PROPOSAL

On September 27, 1993, President Clinton announced that "the U.S. will undertake a comprehensive approach to the growing accumulation of fissile material from dismantled nuclear weapons and within civil nuclear programs." As one of a number of nonproliferation measures, the United States would

Propose a multilateral convention prohibiting the production of highly enriched uranium or plutonium for nuclear explosives purposes or outside of international safeguards.¹

A similar plan was proposed by various groups as long ago as 1954. As recently as December 1992, the United Nations General Assembly had overwhelmingly requested the Conference on Disarmament "to pursue its consideration of the question" of "cessation and prohibition" of such production.

In prompt response to the U.S. proposal, the General Assembly in December 1993 recommended by consensus in Resolution 48/75L

the negotiation in the most appropriate international forum of a non-discriminatory, multilateral and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons and other nuclear explosive devices.

¹The International Atomic Energy Agency (IAEA) defines HEU as "uranium enriched to 20 percent uranium-235 or more" (*IAEA Safeguards Glossary*, 1987, p. 11). We define HEU to also include uranium with 20 percent or more uranium-233.

The resolution's most important addition to the U.S. proposal was the requirement that it be "nondiscriminatory," i.e., that it apply equally to states with and without nuclear weapons.

For more than a year the treaty has been an agenda item at the UN's Conference on Disarmament. The Conference delayed approval of a mandate for negotiation, mainly because of disagreements over the wish of several states to enlarge the scope of the treaty to include existing stocks of fissile material and not just new production. Approval of the mandate finally came in March 1995, with the explicit understanding that both past and future production as well as the management of fissile material could be considered.²

SCOPE

Neither the U.S. proposal nor the UN General Assembly resolution required a cutoff of production of nuclear material for military uses not related to nuclear weapons, e.g., naval reactors, or of safeguarded weapon-usable material employed for civilian purposes.³ As President Clinton explained in a letter to Congressman Stark on October 20, 1993,

²Report of Ambassador Gerald E. Shannon to the Conference on Disarmament, March 23, 1995.

³Several terms are used frequently in this report and are defined below. *Weapon-grade plutonium (WG Pu)* is defined as plutonium containing less than 7 percent of Pu-240. Pu-240 has two undesirable characteristics for bomb-making—the critical mass is about four times as large as Pu-239; and Pu-240's spontaneous fission neutrons cause pre-initiation and yield uncertainty and degradation. WG Pu in this report includes both the Department of Energy's (DoE) super-grade and weapon-grade plutonium. *Reactor-grade plutonium (RG Pu)* is plutonium with 7 percent or more of Pu-240. It includes both DoE's fuel-grade and reactor-grade plutonium. Making a bomb with at least a one kiloton yield with RG Pu would take somewhat more material than with WG Pu. But, plutonium of practically any isotopic composition is *weapon-usable plutonium* and can be used to make nuclear bombs. However, we do not consider plutonium that has not been separated from intensively radioactive spent fuel to be weapon-usable.

Weapon-usable uranium is uranium with 20 percent or more of fissile uranium isotopes such as U-235 and U-233. If the concentration is 90 percent or more, it is called *weapon-grade uranium (WG U)* here. Low-enriched uranium (LEU) of, say, 3 percent or 4 percent commonly used in civilian nuclear reactors is well below the 20 percent threshold and, thus, is *weapon-nonusable*.

Sensitive materials discussed in this report are plutonium and highly enriched uranium, and *sensitive facilities* are those that produce or use sensitive materials.

I have not, however, called for a treaty banning all fissile material production. Such a proposal would breach existing U.S. commitments and lead to confrontation with Russia and our allies. This action would divert attention from cooperative efforts to stop proliferation, and undercut the impact of our fissile material initiative on countries currently outside the nonproliferation regime.

In the same letter, the President emphasized that, "The United States does not encourage the civil use of plutonium (Pu). Its continued production is not justified on either economic or national security grounds, and its accumulation creates serious proliferation and security dangers." He expressed support for "tighter fissile material restrictions in regions of instability" and other measures. These statements are similar to those he made on September 27, 1993, when he declared that the United States will "seek to eliminate where possible the accumulation of stockpiles of highly enriched uranium or plutonium . . . [and] explore means to limit the stockpiling of plutonium from civil nuclear programs, and seek to minimize the civil use of highly enriched uranium."

These statements show that the United States recognizes the potential dangers of civilian use of fissile material and the need for measures to deal with those dangers. Although the proposed convention does not directly limit civilian uses of such material, it can open the door to multilateral negotiations on its control. This report explores such a possibility.

The terms of the proposed convention were clarified by Norman Wulf, Acting Assistant Director of the Arms Control and Disarmament Agency (ACDA), in Congressional testimony on March 23, 1994, and by Robert Einhorn, Deputy Assistant Secretary of State, in Congressional testimony on April 19, 1994.⁴ When a U.S. govern-

⁴Mr. Wulf stated "it is important to stress what this proposal would and would not do. It would not require a ban on production of separated plutonium or highly enriched uranium. It would require, however, international safeguards on at least enrichment and reprocessing activities so that the IAEA could verify that any further separation of plutonium or enrichment to high enrichment levels is not for weapons purposes. However, the United States will continue its efforts to prevent the spread of reprocessing and enrichment capabilities.

ment official was asked, informally, if the treaty permitted production of weapon-usable material for purposes of "diplomatic leverage," he unhesitatingly answered, "yes." The treaty, then, if not supplemented by other measures can be construed as an entitlement to produce weapon-usable material. Taking a comprehensive approach as suggested by President Clinton is critical to the control of sensitive material and facilities.

The effect of the proposed treaty is not to stop production of fissile material but to place sensitive facilities and the material produced from them under IAEA safeguards. The treaty is aimed particularly at India, Pakistan, and Israel, which are undeclared nuclear-weapon states and are unlikely soon to join the NPT. The proposed treaty offers a new avenue toward placing their sensitive facilities and material under safeguards.

"In preliminary, informal discussions with other states, we have identified key elements and issues for the proposed cutoff treaty. We envision that states would undertake

- not to produce fissile materials for nuclear explosive devices,
- not to assist other states in activities proscribed by the treaty, and
- to accept IAEA inspections to verify the undertakings of the treaty.

"We envision the treaty to be open to universal membership and, as mentioned above, to be nondiscriminatory in its provisions."

Mr. Einhorn went on to discuss how the United States is dealing with the problem of civilian use of plutonium. "The United States has also begun consultations with several other countries that have major reprocessing and plutonium use programs to explore ways of increasing transparency of plutonium stocks and flows, including international storage and management options that would be supplemental to IAEA safeguards. In these discussions, we are stressing the importance of balancing the supply and demand of separated plutonium in order to avoid the accumulation of unnecessary stockpiles and the need to agree on effective measures to limit and ultimately reduce and eliminate excess separated plutonium.

"As the President has made very clear, however, we are also committed to being a reliable nuclear trading partner and to avoiding confrontation with close friends and allies whose cooperation with us is critical in achieving important nonproliferation goals, such as a comprehensive test ban and a fissile material cutoff. Therefore, for Western Europe and Japan, where there are large, well-established civil reprocessing and plutonium facilities and comprehensive nonproliferation commitments, we will continue to grant prior consent on a predictable and long-term basis for reprocessing of spent fuel and civil plutonium use.

"At the same time we are actively discouraging reprocessing in areas of instability and high proliferation risk."

REACTIONS

The proposed convention has received wide support. The UN General Assembly unanimously called for the negotiation of the treaty. It is supported by all the UN Security Council's Permanent-5 governments, but the United Kingdom and France insist that the treaty must not limit their production of plutonium and HEU put to civilian use.⁵ India would, likewise, support such a treaty on condition that it "must not limit civil uses of plutonium and HEU." Pakistan insists only that the treaty be broadened to require safeguards on existing stocks of fissile materials. Israel has not taken an official position on the proposed treaty other than to join the December 1993 consensus in the UN General Assembly. However, "Israel would probably also insist on a total ban on reprocessing and enrichment in the region as a condition for agreeing to a cutoff."⁶ It is apparent that Israel sees the intimate connection between civilian and military activities and is concerned about sensitive facilities and materials in the Middle East and Persian Gulf.

Below, we will address the extent to which civilian activities can be used as a cover for military activities that the convention proscribes and the extent to which sensitive civilian material can be used to make nuclear explosives. But first, we need to review the facilities, stocks, and flows with which the U.S.-proposed convention and steps beyond it may deal.

⁵All information in this paragraph, except that about Israel, came from Frans Berkhout, *Summary of the Workshop on a Fissile Material Production Cutoff, May 15-16, 1994, Princeton University*, University of Sussex, June 20, 1994.

⁶Frans Berkhout, Oleg Bukharin, Harold Feiveson, and Marvin Miller, "A Cutoff in the Production of Fissile Material," *International Security*, Vol. 19, No. 3, Winter 1994-1995, p. 197. We will frequently cite from Berkhout et al. because it is one of the most thorough analyses of many aspects of the proposed convention.

THIRD WORLD INVENTORIES AND ABILITY TO PRODUCE WEAPON-USABLE MATERIAL

To examine the effects of the U.S. proposed convention and other steps, we first review the current status of inventories and production capabilities of weapon-usable material in various countries. Table 1 shows these data for Third World countries that (1) are undeclared nuclear-weapon states, (2) have facilities that could be used to produce weapon-grade fissile material but because of current political conditions are not trying to produce nuclear weapons, or (3) are believed to be interested in acquiring nuclear weapons but have not been able to obtain the fissile material required. The basis for the inventory and production estimates is described in the appendix.

INVENTORIES

India, Pakistan, Israel, North Korea, and South Africa have weapon-usable material. These five countries plus Brazil and Argentina have the capability to produce such material. Using a typical rule of thumb—that the amount of material required for a kiloton-yield nuclear weapon is 5 kg of weapon-grade Pu, 7 kg of reactor-grade Pu,¹ or 15 kg of weapon-grade uranium—we estimate that the current inventories are enough for India to assemble 85 bombs; Israel, 70 bombs; South Africa, 47 bombs; Pakistan, 13 bombs; and North

¹The critical mass of reactor-grade plutonium is only 40 percent greater than that of weapon-grade plutonium. See Theodore Taylor, "Nuclear Safeguards," *Annual Review of Nuclear Science*, Vol. 25, 1975, p. 413; and Brian Chow and Kenneth Solomon, *Limiting the Spread of Weapon-Usable Fissile Materials*, MR-346-USDP, RAND, 1993, p. 6.

Table 1
Third World Inventories and Ability to Produce Weapon-Usable Material (as of 1995)

[illegible]

Table 1 (continued)

NOTE: All weapon-usable material is weapon grade unless noted otherwise.

^aDesigned or attainable capability in 1995 or within a few years.

^bConsisting of 350 kg of weapon-grade Pu and 100 kg of reactor-grade Pu.

^cMostly reactor-grade Pu.

^dZeroes mean no current inventory or actual production, but the country has the capability to do so.

^e"—" means no inventory or actual production and no capability to do so.

^fIn March 1993, North Korea invoked the 90-day withdrawal provision of the NPT. In June 1993, one day before this withdrawal was to take effect, it "suspended" its withdrawal. Because of these unusual events, North Korea has, from time to time, claimed that it has special status and is not fully obligated by the provisions of the NPT. As part of the October 21, 1994, Agreed Framework between the United States and North Korea, North Korea has pledged to remain a party to the NPT. It remains to be seen whether this will affect North Korea's claim to special status.

Similarly, although North Korea has entered into a full-scope safeguards agreement with the IAEA, the IAEA believes that North Korea's initial declaration made under this agreement is false. North Korea has blocked the IAEA from inspecting sites that would clear up this matter and has impeded IAEA inspections at other sites as well. The U.S.-North Korea Agreed Framework has postponed bringing North Korea into full compliance with its full-scope safeguards obligations for another five years.

^gIn February 1995, Argentina joined NPT. Argentina, as well as Brazilian, nuclear facilities have already been placed under IAEA's full-scope safeguards.

^hIn January 1995, Algeria joined NPT. It has 18 months to place its nuclear facilities under IAEA's full-scope safeguards.

Korea, 4 to 6 bombs.² Figure 1 shows these latent nuclear-weapon capabilities. However, the numbers do not mean that these countries actually have that many assembled bombs. Some or all material may be held only as raw material. Moreover, South Africa has dismantled its bombs and has declared that it has no intention of manufacturing any in the future, but it still holds 700 kg of weapon-grade uranium.³ These numbers merely show the weapon-usable material that is potentially available for making bombs, thus adding to concerns about proliferation.

The proposed convention, however, does not intend to reduce existing inventories or even necessarily to limit their enlargement, or to eliminate production capabilities; rather, it suggests a first step—

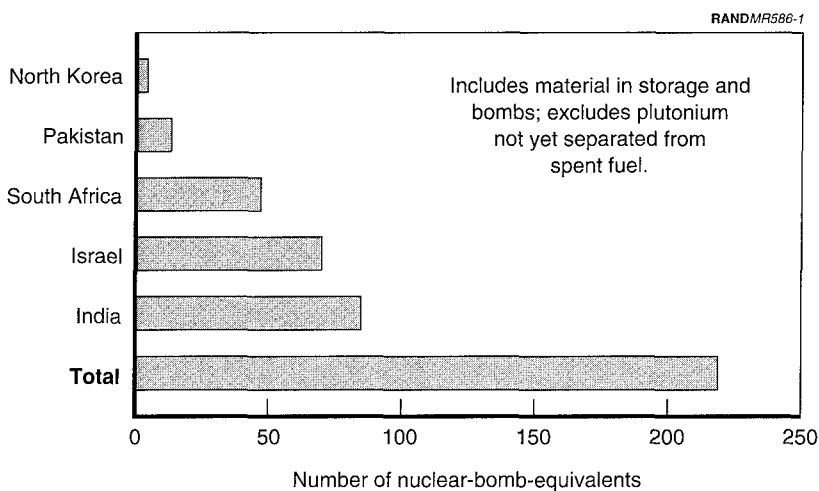


Figure 1—Third World Inventory of Weapon-Usable Material in 1995

²Brazil and Argentina currently have only medium-enriched uranium (MEU) of about 20 percent, which is considered weapon-nonusable. Brazil has about 200 kg of MEU and Argentina 0 to 500 kg.

³The United States has been interested in purchasing and removing the HEU from South Africa, but no agreement has yet been reached.

preventing future fissile production that is unsafeguarded and acknowledged to be for the purpose of making nuclear explosives.

PRODUCTION CAPABILITIES

By the mid-1990s, India will be able to produce enough fissile material for 100 bombs per year; South Africa, 67; North Korea, 50; Argentina, 7; Israel, 3; Pakistan, 2; and Brazil, 1 to 7. Figure 2 breaks out these capabilities. Again, these numbers reflect countries' *ability* to produce, not the amount that they *intend* to produce. South Africa, Brazil, and Argentina have declared policies not to build nuclear bombs; but political scenes can change.

In addition to these countries, France, the United Kingdom, Russia, and Japan are the countries most interested in civilian plutonium use; they have inventories of and production capabilities for separated plutonium. France currently can separate 16,000 kg of plutonium from spent fuel annually; the United Kingdom, 9,500 kg; Russia, 4,000 kg; and Japan, 900 kg (this number will rise to 8,900 kg

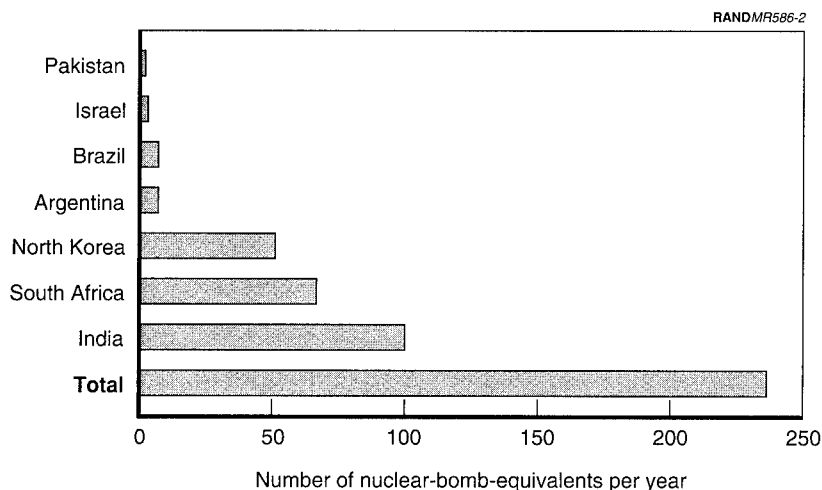


Figure 2—Third-World Ability to Produce Weapon-Usable Material in the Mid-1990s

within a decade).⁴ The total plutonium separation capability in these countries is 30,000 kg per year now and will be 38,000 kg per year a decade from now. In units of primitive bomb-equivalents, this reprocessing capacity can produce enough material to make 2,300 bombs annually in France; 1,400 bombs in the United Kingdom; 570 bombs in Russia; and 130 bombs in Japan (1,300 bombs a decade from now). The total reprocessing capacity in all of these countries is sufficient to produce enough material for 4,400 bombs a year currently (and 5,600 bombs a year within a decade).⁵ Figure 3 shows this contribution to potential proliferation. The diversion or theft of even a small fraction of this material would be enough to make many nuclear bombs.

There are two missing elements in Figure 3: China and highly enriched uranium. Both would add to the totals of potential nuclear explosives. However, there is little open information on China's plutonium production capabilities or plans for civilian use.⁶

⁴Some of Japan's future capability may be postponed for reasons of economics. We determined the plutonium separation capabilities of these countries by examining their existing operating reprocessing facilities and those under construction. The plutonium content in spent fuel depends on the reactor type and burnup level. We assumed that spent fuel from light water reactors contains 1 percent of plutonium of all isotopes; Magnox spent fuel, 0.3 percent; and spent fuel from advanced gas-cooled reactors, 0.45 percent.

⁵Analysts often estimate the plutonium production rate from the number of nuclear reactors using plutonium as fuel. Our estimate based on reprocessing capacity is equivalent to about 20 percent of the power plants using plutonium. Nuclear installed capacity worldwide as of October 31, 1993, was 355 gigawatt electric (GWe). It is expected to grow to 381 GWe by the year 2000 (Nuclear Engineering International, *World Nuclear Industry Handbook*, 1994, pp. 13-14). Most of these reactors are light water reactors (LWRs). Although plutonium-bearing mixed-oxide (MOX) fuel can be used in a LWR's full core, it has been planned that in the near term only a third of the core will be fueled with MOX fuel. In this report, plutonium consumption estimates are based on one-third core of MOX. We estimate that the reprocessing capability within a decade will be sufficient to provide MOX fuel for about 20 percent of the year 2000 reactor capacity. In other words, there will be enough plutonium separated each year to support thermal recycle in about 20 percent of this capacity, and each reactor participating in thermal recycle will use MOX fuel in one-third of its core.

⁶In April 1995, the chief engineer of the China National Nuclear Corporation's nuclear fuel bureau told an international conference that China plans to complete a 25 MW(e) experimental fast reactor soon after the year 2000, fueled by a "multi-purpose reprocessing plant" and that a larger, 400-800 metric ton per year reprocessing plant could be put into operation in the 2010s. Ann MacLachlan, "China-U.S. Nuclear Talks Begin; CNNC Says China Will Reprocess," *Nucleonics Week*, April 13, 1995, pp. 6-7.

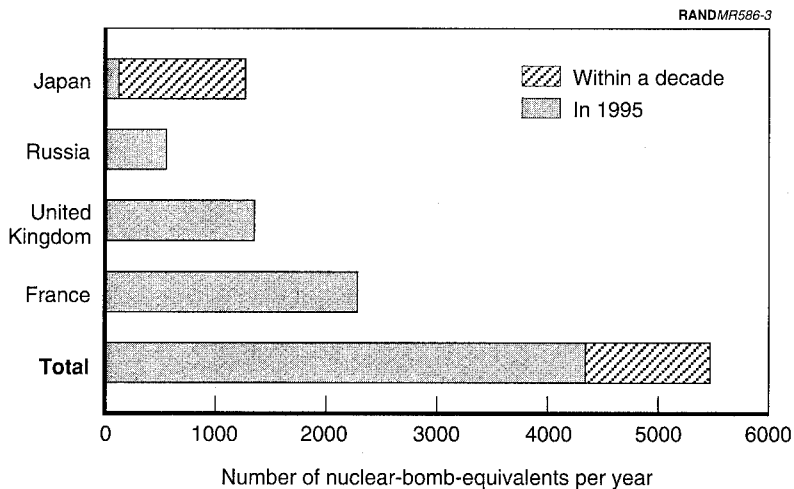


Figure 3—Reprocessing Capability in Major Countries That Use Plutonium in Civilian Applications

Because HEU is not needed to generate civilian nuclear power, it could eventually be banned.⁷ But if electricity continues to be generated with nuclear energy, some uranium enrichment facilities are likely to continue operating in the world. Rogue countries can switch their enrichment plants to produce HEU instead of low-enriched uranium, in the event of a breakout. Such a switch could be rapid in enrichment facilities using the gas centrifuge. To control this problem, the international community would need to limit these sensitive facilities to the nuclear-weapon states and to as few sites as possible in nonnuclear-weapon states.

⁷Currently, HEU is not used in civilian nuclear-power plants. It is used in some research reactors and in a few fast reactor demonstrators. As the continued efforts of converting research reactors for using nonweapon-usable uranium take full effect, HEU can eventually be eliminated from most research reactors. The use of HEU in naval reactors will be discussed in Chapter Five.

PROLIFERATION RISKS AND POSSIBLE CONTROLS

This report will focus much more on plutonium control, because plutonium and its facilities are not needed in any form and yet both are spreading. One major problem of plutonium use is the imbalance between production and consumption. The IAEA estimated that civilian separated plutonium stockpiles worldwide will increase from about 87 metric tons (tonnes) in 1992 to a maximum of 160 tonnes in 1999 and will decline only gradually to 132 tonnes by 2005.⁸ At its maximum, the material is enough for 23,000 bombs.

Recognizing the risk, the U.S. 1993 Nonproliferation and Export Control Policy seeks to "eliminate where possible the accumulation of stockpiles." Such elimination would still leave sizable amounts of weapon-usable material in the system. In other words, even if countries could do their best to balance the production and consumption of separated plutonium, large amounts of plutonium will always remain as long as there are commercial activities in plutonium.

Within the reprocessing plant itself, plutonium is contained in the material flow from one stage to another. After plutonium is separated from spent fuel, it may be held in the form of plutonium dioxide in a storage area. Then, the plutonium dioxide is transported to a fuel fabrication site, which may not be collocated with the reprocessing site. If plutonium dioxide is diverted from the storage area or during transit, the plutonium can be easily separated from the oxides for use in bombs. In the case of Japan, transoceanic shipment has been used. The diversion danger is serious, especially when the material is shipped frequently and security is not adequate. Upon arrival, the plutonium oxide will be held at a fabrication plant until it is processed into MOX fuel rods and assemblies. The finished fuel assemblies will be held at the fabrication site for a while, shipped, and again be held at the reactor sites until they are loaded into reactors. These holdings and flows of plutonium-bearing material in the

⁸Separated plutonium is expected to be kept in the United Kingdom, Japan, Belgium, the United States, Russia, France, Germany, India, Switzerland, and the Netherlands (International Atomic Energy Agency, *Problems Concerning the Accumulation of Separated Plutonium*, IAEA-TECDOC-765, a report of an Advisory Group meeting held in Vienna, April 26-29, 1993, pp. 7-9).

plants and in transit are a necessary part of the commercial process of producing and using plutonium.⁹

We estimate that the plutonium in process is equal to about a year's throughput of a reprocessing plant, even after countries have done their best to balance the plutonium production and use.¹⁰ Thus, when the reprocessing plants are operating at their designed capacity, there will be 4,400 to 5,600 bombs worth of plutonium in the system.¹¹ It would be difficult to protect this material at all times from subnational diversion. Worse yet, it is impossible to protect it from seizure by the host countries. In other words, no agency can prevent a country, at a breakout, from seizing the material within its own boundaries and using existing facilities to produce material for nuclear weapons. This is why we view access to *both* safeguarded and unsafeguarded material and facilities as the criterion for evaluating alternatives.

Eliminating plutonium use would not create an economic hardship because the added cost to process the radioactive and toxic plutonium for use is more than its fuel value.¹² But it will not be possible

⁹For example, Japan recently revealed that at the end of 1993, it held 4,684 kg of plutonium in the holdings and flows at its reprocessing plant, in its plutonium fuel fabrication facilities, and in fresh plutonium fuel at various reactors. This plutonium is enough to make 670 bombs (see *Nuclear Engineering International*, March 1995, p. 17).

¹⁰Few analyses have attempted to estimate the amount of plutonium-bearing material in working processes and inventories; hence, estimates remain largely uncertain. The new MOX fabrication plant in Hanau, Germany, is licensed to contain a plutonium inventory of 2.5 tonnes (Thomas Roser, "Hanau MOX: Why We Are Waiting," *Nuclear Engineering International*, October 1992, p. 37). Using this number, we estimated that that amount is equivalent to 37 percent of the fabrication plant's annual throughput. Assuming that the plutonium inventory is the same at the reprocessing plant, the inventory at the reprocessing and fabrication plants would be at 74 percent of the reprocessing plant's yearly throughput. To this, we still need to add the amount of plutonium in transit from the reprocessing plant to the fabrication plant and to the reactor sites, and the plutonium in storage at the reactor sites awaiting refueling. Thus, the total plutonium inventory in the system would be close to a year's actual throughput at the reprocessing plant.

¹¹It is possible that reprocessing plants will operate below designed capacity. One can adjust the numbers accordingly. In any case, the amount of plutonium reprocessed per year is expected to be large if plutonium use is commercialized.

¹²See Chow and Solomon, *op. cit.*, particularly pp. xvii and 30-31. That study compares the cost of using plutonium as fuel with that of using uranium. The high radioactivity of plutonium requires remote handling in the fabrication of plutonium-

to eliminate this sensitive material if civilian fissile material production activities proceed as currently planned.

bearing fuel rods. That safeguard is not necessary with uranium fuel fabrication, which is therefore much less expensive. Plutonium is carcinogenic, and great care is needed to prevent it from entering a worker's body via the respiratory system. Thus, the fabrication of plutonium-bearing fuel also requires substantially greater use of air locks and isolation facilities. Again, this makes plutonium fabrication much more costly than uranium fabrication. In addition to fabrication, expensive equipment and facilities are needed to separate plutonium from spent fuel. Most of the current nuclear power plants worldwide operate in the once-through mode, which does not reprocess spent fuel for plutonium and uranium. However, the use of plutonium as fuel would reduce the cost of uranium and enrichment. Chow and Solomon found that the added costs of separating and fabricating plutonium are higher than the savings in using less uranium fuel. Therefore, plutonium is not economical to use.

THE PROPOSED CONVENTION'S EFFECT ON PROLIFERATION

Though formally nondiscriminatory, the practical effect of the proposed convention will be directed toward some countries more than others. We discuss the distribution of effects in this chapter. We then deal more generally with the ways the new treaty would restrict (or not restrict) access to weapon-usable materials. Finally, we consider the time lag before the new treaty comes into effect.

EFFECTS ON SPECIFIC COUNTRIES

Which countries would be affected by the proposed convention? The cutoff of unsafeguarded production would have no effect on the domestic activities of nonnuclear-weapon states that are parties to the NPT. They have already agreed to place all of their nuclear activities under safeguards and not to produce nuclear explosives.

The cutoff might have some effect on nuclear-weapon states that are still producing material for nuclear weapons or that have not committed themselves to stop. But all the nuclear-weapon states have ceased producing weapon uranium; and all but possibly China have ceased producing plutonium for weapons.¹ The convention, however, can formalize the commitment to permanently stop this unsafeguarded production. It is uncertain whether the cessation would

¹See Tom Zamora Collina, "NPT: Little Time, High Stakes," *ISIS Report*, Institute for Science and International Security, Washington, D.C., September 1994. See also Berkhout et al., op. cit., pp. 175 and 178; and Pearl Marshall, "BNFL Halts Military Pu Production from Calder Hall Magnox Station," *Nucleonics Week*, April 27, 1995, pp. 13-14.

affect China's nuclear modernization program, because it may have already produced all the weapon-grade material it needs. The treaty could also place the production facilities in nuclear-weapon states under IAEA safeguards. The advisability of safeguarding sensitive facilities in declared nuclear-weapon states hinges on the tradeoff between an implementation cost on the order of \$100 million per year² and the enhanced image of fairness in applying the safeguards nondiscriminately to nonnuclear- and nuclear-weapon states alike.

The proposed convention can also formalize the commitment of nonnuclear-weapon states outside of the NPT to not produce material for weapons. The treaty has the added effect in these states of imposing IAEA safeguards. Pakistan halted weapon uranium production in 1991. Brazil's HEU production is likely to continue even under the convention because Brazil will continue to claim that its production is for naval reactors. Currently, Israel is not a member of the Conference on Disarmament; the international community is very interested in having Israel join the convention if it does not join the NPT in the near term, but the prospects for both may hinge on the actions of other states in the Middle East. In the case of North Korea, it agreed in 1991 with the Republic of Korea to end reprocessing and signed a nuclear accord in October 1994 with the United States requiring it eventually to dismantle its reprocessing facility. The accord, however, allows the facility to remain intact for at least the next five years. Given that North Korea has not in the past honored its pledges under NPT and other agreements, it could decide in the future to keep the facility after all.

The nation most affected by the convention could be India. India, in addition to placing its production facilities under safeguards, would be obligated to stop production of weapon-usable material for nuclear explosive purposes. However, India could continue the production by claiming that the weapon-usable material is for the fueling of breeders, research reactors, and naval reactors.

²Berkhout et al., *op. cit.*, pp. 183, 186, and 193-194.

GENERAL EFFECTS ON ACCESS TO WEAPON-USABLE MATERIAL

The proposed convention represents a political commitment not to use newly produced fissile material for nuclear explosives. However, it would have no effect on the number of nuclear weapons potentially available on short notice. This is because the proposed convention permits the production and stockpiling of weapon-usable material as long as it is not avowedly for nuclear weapons.

Once plutonium has been separated from highly radioactive spent fuel, it is not difficult or time consuming to convert this plutonium into metal (the chemical form most appropriate for weapon use) and to shape it as required for use in a nuclear weapon. After separation, the plutonium is likely to be found in the form of plutonium dioxide. The facilities required to convert the plutonium into metal are in general quite simple. Countries desiring such facilities might try to claim that they are needed for some research purpose. Or, since the facilities are small, they might be constructed clandestinely. Construction of the facilities could take about six months, and it is unlikely that the construction would be detected. The first warning could come when the plutonium dioxide was removed from its safeguarded storage, but by then the conversion into metal would take only days or weeks.³

³The process is only slightly more complicated if the plutonium dioxide has been converted into MOX fuel for use in LWRs or fast reactors. The facilities required for extracting the plutonium would again be small and simple. It might take six months to a year to build these facilities, but again, the construction could be done clandestinely with little chance of being detected. Or a country might claim that the facilities were fulfilling a legitimate peaceful purpose, such as scrap recycling from a nuclear fuel fabrication facility. As with the plutonium dioxide, the first warning of the conversion of the MOX fuel into nuclear weapons would only occur when the extraction of the plutonium began. But again, by this time it would take only days or weeks before the plutonium metal was produced (Albert Wohlstetter et al., *Swords from Plowshares*, the University of Chicago Press, 1977, pp. 153-155).

The nonnuclear components of the nuclear device could be developed in parallel, and the testing of these components would not require plutonium metal. Both the United States and the United Kingdom⁴ developed nuclear weapons this way, and the nonnuclear components could be completed months or even years before the production of the plutonium metal. Again, this development could be clandestine. Or it could be claimed that the development was for conventional armaments research. The conversion of metallic plutonium into weapon parts and the insertion of these parts into otherwise completed nuclear weapons would take few additional days.

In other words, the proposed convention does not prevent a country from assembling nuclear bombs within days or weeks after a breakout.

As discussed in the previous subsection, if civilian use of plutonium is allowed, plutonium will always be present in large quantities. The question, then, is whether placing these materials and facilities under IAEA safeguards is a significant benefit. The advantage of safeguards is to allow detection of material diversion. Indeed, as long as a state observes the convention, it might not be able to assemble nuclear bombs. But, because rogue countries could, and likely would, produce and stockpile nuclear bomb components other than fissile material in advance of breakout, the time from weapon-usable material to first nuclear weapons would be short; and the number of weapons even in the first new batch could be quite sizable. Also, undeclared nuclear-weapon states might already have assembled nuclear weapons; and they would be allowed to keep these weapons under the treaty.⁵

⁴As the head of the British nuclear weapon development program, W. G. Penney suggested the following scheme for development. He said that the manufacture of an atomic bomb fell into two parts: first, the production of the active material and, second, the manufacture and assembly of the components causing the explosion of the active material. The second part of the work could be begun and completed without the need to use fissile material at any stage (quoted in Margaret Gowing, *Independence and Deterrence: Britain and Atomic Energy, 1945-1952, Vol. I—Policy Making*, St. Martin's Press, 1974, p. 180).

⁵Berkhout et al., op. cit., p. 197, recognize that "In the Middle East, and indeed more generally, it is clear that even if separated weapons-usable materials are placed under international safeguards, they present a serious potential for breakout in a crisis, and an ongoing risk of diversion and theft."

The convention would ban assistance to others in the production of material for weapons. The ban would close a loophole in the NPT, which explicitly prohibits only nuclear-weapon states from helping nonnuclear-weapon states acquire nuclear explosives. Article II of the NPT, which describes the key obligations of nonnuclear-weapon states, contains no such prohibition.

The convention would have a far greater effect if it brought governments across a psychological threshold to adopt other nonproliferation measures as well. The dangers result only if the convention is negotiated in isolation, which would give the convention only limited value and—to the extent that it establishes an “entitlement” to produce weapon-usable material—may actually be counterproductive. Proposals for additional measures can make explicit that the current proposal will in no way imply a permanent entitlement to produce weapon-usable material.

President Clinton did not propose a cutoff in isolation but rather as one element of a “comprehensive approach to the growing accumulation of fissile material.” The most attractive effect of his proposal can be the opening of the door for negotiating other nonproliferation measures concurrently or subsequently. Before addressing such measures, we need to examine the time period during which the current plans might be negotiated—and the implications for the timing of supplemental measures.

THE TIMELINE FOR NEGOTIATIONS

For more than a year, the Conference on Disarmament delayed the establishment of an ad hoc committee to pursue a cutoff proposal, mainly because there was disagreement on whether existing fissile material should be covered in any treaty to be negotiated. To discuss the timeline for bringing the existing proposal into effect, we propose the following illustrative scenario: Start with the Conference on Disarmament “mandate” to begin negotiations in 1995. Given the complexity of the issues to be debated, it would be surprising if a draft treaty could be concluded in less than three years. Using the Chemical Weapons Convention as a benchmark, it would be optimistic to believe that enough countries would ratify the convention sooner than two years thereafter. And, given the experience with the NPT and the extensive safeguards requirements under the proposed

convention, it would again be surprising if the operations required by the convention could be fully under way sooner than two years after its entry into force. This is a total of seven years—bringing the convention into full operation in 2002 at the earliest. In the words of Department of State official Fred McGoldrick, “We do not expect that a cutoff treaty and its associated safeguards arrangements will be concluded overnight.”⁶ An unnamed “senior U.S. official” was more outspoken. In February 1995, he estimated that a global ban on the production of fissionable material would “take forever.”⁷

This is not to say that the proposed convention cannot be concluded in less than seven years. After all, the Strategic Arms Reduction Treaty II (START II) required much less time to negotiate. But START II was negotiated after years of groundwork in START I and was bilateral, and the negotiations were concluded in a cooperative atmosphere. By contrast, the proposed convention is multilateral and raises new and difficult issues of scope, verification, financing, and drafting.⁸ On these issues, the atmosphere in the Conference on Disarmament is not currently one of good will; and the issues are likely to be debated sequentially (rather than, as with the Comprehensive Test Ban Treaty, concurrently). All this could result in a far longer period than seven years before a cutoff convention goes into effect. In the interim, more sensitive facilities can be constructed and more sensitive material produced.

This suggests that waiting for the convention to come into effect before pursuing next steps may mean waiting for a very long time. Such a prospect raises the question of negotiating other measures in an accelerated, overlapped, or even concurrent fashion with respect to the negotiation of a cutoff convention.

⁶“U.S. Fissile Materials Initiatives—Implications for the IAEA,” in IAEA Symposium on International Safeguards, Vienna, March 14–18, 1994.

⁷R. Jeffrey Smith and David B. Ottaway, “U.S. Wages Last-Ditch Campaign for Permanent Nonproliferation Pact,” *Washington Post*, March 1, 1995, p. A4.

⁸Berkhout et al., op. cit., p. 201, raise a number of proposals to reduce the risks of a cutoff treaty; all of their proposals would add complexity to the negotiations.

NEXT STEPS: OPTIONS, OBSTACLES, AND MITIGATING MEASURES

We now turn to further steps that, when added to the proposed convention, could help complete President Clinton's "comprehensive approach." We focus on two options that we consider particularly promising: stockpile controls and a total production cutoff. We describe obstacles to implementing these additional steps and what might be done to minimize those obstacles. We then briefly consider a more discriminatory and less far-reaching alternative to these steps. We conclude with some observations on a comprehensive negotiating approach consisting of the proposed convention and the two most promising additional steps.

TWO PROMISING OPTIONS

The U.S.-proposed convention might be supplemented in two ways: (1) disposition of existing stocks of weapon-usable fissile material and (2) a total cutoff—the cutoff of production of weapon-usable material for all purposes, military and civilian.

Stockpile Disposition

Stockpile disposition covers various degrees of control by various means. The control might only mean the safeguarding of stocks that are currently unsafeguarded. In the subsection, "General Effects on Access to Weapon-Usable Material," in Chapter Four, we have shown that merely safeguarding stockpiles will not reduce a country's ability to turn part of the material into nuclear weapons with short notice. An effective control would have to involve the actual reduction of

existing and future stocks whether for military or civilian purposes, or the transfer of such stocks to reliable custody.

Controls on existing unsafeguarded stocks have been advocated in the Conference on Disarmament by Algeria, Egypt, Indonesia, Iran, and Pakistan. All of these nations are concerned about the possibility that other nations—perhaps regional neighbors—will retain potential nuclear weapons. Pakistan has proposed that all parties to the convention first declare their stocks and then follow a “schedule for the progressive transfer of these stocks to safeguards, so that the unsafeguarded stocks are ‘equalized’ at the lowest possible level The transfer should first be made by those states with the largest stockpiles, in the global and the regional context. If this process of reducing unsafeguarded stockpiles is not accepted, the Convention will make no impact on stemming the proliferation of nuclear weapons.”¹ Egypt has recently escalated its public opposition to Israel’s nuclear program.² So even if Pakistan reduces its pressure in the Conference on Disarmament for controls on existing stockpiles, other advocates may not.

The United States and most other nations, however, have made it clear that they do not envisage the convention as applying to material produced before the convention takes effect. The issue of whether to include existing stockpiles delayed for more than a year the process of approving a “mandate” for the Conference on Disarmament to negotiate a treaty. Special Coordinator on the Cut-Off, Ambassador Shannon of Canada, considered this issue perhaps “the principal reason” for the impasse.³ However, Ambassador Shannon stated “my view that the absence of such a reference to stockpiles does not mean that stocks cannot be addressed once an ad hoc negotiating committee has been mandated and established.”⁴ All that the Conference on Disarmament could agree upon before

¹Prepared statement by the Ambassador of Pakistan at the Plenary of the Conference on Disarmament, June 9, 1994.

²Peter Waldman, “Egypt Confronts Israel on Nuclear Arms,” *Wall Street Journal*, January 11, 1995, and Clyde Haberman, “Israel Eyes Iran in the Fog of Nuclear Politics,” *New York Times*, January 15, 1995.

³*Report of the Special Coordinator on Cut-Off to the Conference on Disarmament*, Geneva, September 7, 1994.

⁴*Ibid.*

adjournment in September 1994 was, "There was consensus among members that the Conference was the appropriate forum to negotiate a treaty on this issue. While there was no agreement on a mandate for an Ad Hoc Committee, there was agreement, in principle, that an Ad Hoc Committee on this issue should be established as soon as a mandate has been agreed."⁵

Only on March 23, 1995, was there agreement on a mandate. Ambassador Shannon announced, "[I]t has been agreed by delegations that the mandate . . . does not preclude any delegation from raising for consideration in the Ad Hoc Committee . . . production of fissile material (past or future) but also . . . other issues, such as the management of such material."⁶

Total Cutoff

The other suggested expansion of the basic proposal is the total cutoff. As the Indonesian Ambassador to the United Nations stated, "We are concerned at the accumulation of vast quantities of weapons-grade plutonium from civilian reactors even by some non-nuclear states. To date, no satisfactory solution to this problem has been devised and the appropriateness of civilian processing of spent fuel has become yet another source of contention."⁷ North and South Korea have expressed concern at Japan's extensive accumulation of separated plutonium even as the two Koreas pledged in 1991 to forgo reprocessing or enrichment on the Peninsula. Israel, as noted above, would be concerned about enrichment or reprocessing by its Middle East and Persian Gulf neighbors. Some U.S. government officials argue privately that the proposed treaty is a good first step toward a more comprehensive cutoff.

⁵*Draft Report of the Conference on Disarmament to the General Assembly of the United Nations*, September 1994.

⁶Report of Ambassador Gerald E. Shannon to the Conference on Disarmament, March 23, 1995.

⁷Statement at the General Debate in the First Committee on Disarmament and International Security, New York, October 19, 1994.

OBSTACLES

Several obstacles stand in the way of eliminating stockpiles or cutting off production of weapon-usable materials for any purpose. Several governments have taken a strong position against such actions. Questions can be raised regarding the future source of fuel for U.S. nuclear-powered ships. Adding steps to those already proposed could draw out the negotiating process over a much longer time. We briefly treat the latter two problems first, then concentrate for the rest of this subsection on the rationales driving opposition from other nations and a critique of those rationales.

Naval Reactors

A cutoff of HEU production could affect naval reactors in at least the United States. This raises potential national security obstacles. The effect on the United States would depend on how much of an HEU stockpile the United States plans to hold. The United States uses an estimated four tonnes of HEU annually for naval reactors, while the estimated surplus of U.S. HEU in 2003 will be over 400 tonnes.⁸ Saving 88 tonnes would support nuclear propulsion until the year 2025. In the meantime, alternatives for naval propulsion can be explored, including reactors using nonweapon-usable uranium such as those currently used by the Chinese in their naval reactors. Or there could be provisions allowing HEU production to be restarted only under careful monitoring.

Delayed Effectiveness

What would be the time frame for disposition of existing military and civilian stockpiles or a total cutoff? If one used as a benchmark the illustrative seven-year time period needed to bring into full effect the current U.S.-proposed convention, and if the next treaty dealt with the safeguarding of existing stocks and a subsequent treaty with a full production cutoff and the disposition of existing stocks, the entire set of measures could take 21 years to bring into operation. Admittedly, 21 years is only an illustrative figure, but it is clear that sequential ne-

⁸Chow and Solomon, *op. cit.*, p. 12.

gotiation will be very time consuming. During this time, sensitive facilities may have generated hundreds or thousands of additional weapon-equivalents in the Third World and tens of thousands in the major plutonium-producing states. Should the United States bring up the issues of stockpile disposition and a total cutoff? If so, should the negotiation process on these two issues start sooner?

Government Attitudes

As noted above, the United Kingdom, France, and India specifically oppose any limits on "civilian" production in the proposed convention. Brazil, which claims to be producing enriched uranium for naval reactors, might similarly oppose a total production cutoff. To keep these countries' cooperation, the United States has agreed not to limit civilian and nonexplosive military production in the proposed convention. Instead, the United States has made a suggestion "to limit the stockpiling of plutonium from civil nuclear programs" and "to constrain fissile material production in regions of instability and high proliferation risk."⁹ However, we have shown that the plutonium stockpile cannot be kept at a low and safe level if civilian use is allowed. Because civilian use of plutonium is a global problem and because limits on plutonium are likely to be perceived as equitable only if adopted on a global basis, it seems questionable whether the plutonium problem can be solved solely by regional means.

Pakistan raised an obstacle even to a Conference on Disarmament negotiating mandate—proposing the "equalization" of unsafeguarded existing stocks "at the lowest possible level." This could affect all nuclear-weapon states as well as Israel, India, and Pakistan itself. As we have pointed out, safeguarded stocks, however, still represent a serious latent capability. Reduction of the material, or transfer of it to reliable custody, would degrade the latent capability; but Pakistan's proposal avoids that issue.

The opposition of states such as those mentioned above, plus Russia and Japan, would seem to kill the prospects for total cutoff and stockpile reduction. However, there is growing domestic opposition to civilian plutonium programs in all of the above countries except

⁹Fact sheet on Nonproliferation and Export Control Policy, September 27, 1993.

perhaps India. Some of this opposition is based on environmental or proliferation concerns. But the most effective opposition is based on economic considerations. The breeder program in Germany was canceled in 1991, and in the United Kingdom in 1994. In recent years, the breeder program in Russia has also been scaled back. Even France, the most ardent supporter of breeder development, has seen its breeder program collapse. Japan's schedule of plutonium activities has also recently been stretched out. In 1994, Germany changed the law to allow the direct disposal of spent fuel, instead of requiring reprocessing first. In December 1994, a number of German utilities started to cancel their reprocessing contracts with British Nuclear Fuels Ltd.¹⁰

Only in Japan can the finance ministry and electric utilities hope to ignore the hundreds of millions of dollars in annual losses imposed by programs for the civilian use of plutonium. The economic losses from the plutonium reprocessing facilities in the United Kingdom and France are reduced by long-term contracts from other countries. But the losses resulting from plutonium use are not thereby eliminated, only shifted among countries and stakeholders.

Moreover, security dimensions may grow in importance for the plutonium-producing nations. For example, under the Joint Declaration for a Non-Nuclear Korean Peninsula that the two Koreas signed in 1991, they have committed only to "not possess facilities for nuclear reprocessing and uranium enrichment." They would still be allowed to possess plutonium for "peaceful purposes." In the past, North Korea has argued that if Japan possesses plutonium, then so should North Korea. South Korea can argue the same way. But it is in Japan's security interest that they do not.

Given this state of affairs, it is reasonable to ask why these plutonium programs exist in the first place and why they have not already been canceled. From the dawn of the nuclear age to the 1970s, countries thought that uranium resources for power generation were rapidly running out and that plutonium would be needed soon. These plutonium programs were started to extend eventually the nuclear energy supply. Since the 1970s, projections of civilian nuclear power

¹⁰"Business Worries Cloud Prospects for Nuclear Reprocessing Complex," *Financial Times*, January 23, 1995, p. 6.

growth have been revised severely downward,¹¹ and additional types and amounts of uranium ores have been discovered. Still, some countries are unwilling to alter their original plan of eventual plutonium use because they remain worried that they would not have sufficient time to develop an alternative to plutonium. Technically, the use of plutonium in breeders, not in thermal reactors,¹² can expand the uranium resources by a factor of 50 or more.

But in a recent study, it was determined that plutonium use in breeders will be uneconomical for 50 years or more.¹³ That study recommended that the time horizon be extended even more by improving the efficiency of thermal reactors and searching for additional uranium resources at current and higher prices. Moreover, there will always be enough plutonium in the spent fuel to support even an optimistic plutonium-based breeder reactor buildup in the event that breeders are needed unexpectedly. Therefore, countries do not need to plunge into plutonium use prematurely. Some argue that countries such as Japan have already spent billions of dollars on plutonium facilities and need to keep those facilities operating to recoup their investment. We find that plutonium activities are so uneconomical that they are unlikely to recoup much of their past sunk costs. As Secretary of Energy Hazel O'Leary said recently, "Some

¹¹In 1977, the Nuclear Energy Agency projected that the nuclear capacity in OECD countries by 2000 would be 1,200 gigawatt-electric. As that year draws near, the projection declines precipitately. By 1992, the projected year-2000 capacity was only 300 gigawatt-electric. The projection was reduced by a factor of four in only 15 years.

¹²Thermal reactors include the current commercial power reactors—light water reactors and heavy water reactors.

¹³See Chow and Solomon, *op. cit.* That study compared the costs of generating electricity by breeders and by light-water reactors. Most current power plants are light-water reactors. In Chapter Three of the present paper, we discuss why the reprocessing and fabrication of plutonium are expensive. In addition, the capital cost of a breeder is expected to be considerably higher than that of a light-water reactor. One reason for the higher cost is the use of liquid sodium, instead of water, as a reactor coolant. Sodium is highly chemically active and opaque and forms radioactive isotopes under irradiation. These characteristics make equipment for safety and operating and maintenance, including fueling and refueling, more complicated and costly. Chow and Solomon integrate these factors and determine at what uranium price and when the use of breeders will be more economically attractive than light-water reactors.

think plutonium is a very valuable commodity which could enter the marketplace. I think that's balderdash."¹⁴

In spite of the poor prospects of plutonium, countries may still refuse to terminate or phase out their programs using plutonium. The momentum continues, and years of financial and human commitments to the programs have created a vested interest and political clout to protect these programs. Some governments may seek to "grandfather" plutonium programs to guarantee them a weapons option. Once large costs are sunk, the lower remaining costs make the economics of plutonium less unattractive.

MITIGATING THE OBSTACLES

Several elements cumulatively can weaken the opposition to a full production cutoff and stockpile disposition of weapon-usable fissile material:

- **Press the logic that only such measures will have a significant effect on proliferation.** The United States last tried this in the late 1970s. But it did so in a manner that seemed to threaten bilateral commitments to allow U.S.-origin material to be reprocessed, and the United States was a relatively isolated voice in a world that assumed the inevitability of plutonium fuel cycles. Since then, the politics and economics of plutonium have deteriorated and these facts are widely recognized. As long as the United States does not renege on its commitments to its allies—but rather seeks voluntary negotiation of new arrangements—it will be widely perceived as reasonable and nonthreatening.
- **Point to the U.S. example—the abandonment of civilian uses of plutonium—and add other examples, e.g., Germany. Also point to regional opponents of such programs, e.g., North and South Korea, and, perhaps ultimately, China with respect to Japan's program and perhaps Israel with respect to its neighbors' programs.** Although plutonium is a global problem, many domestic and regional groups might oppose plutonium before a global convention went into effect. Germany, once a strong advocate of

¹⁴Mark Obmascik, "Selling Waste 'Balderdash'," *The Denver Post*, March 26, 1994.

plutonium fuel cycles, has steadily cut back its programs. North and South Korea agreed in 1991 to abandon reprocessing and enrichment on the Peninsula; they both have expressed concerns about Japan's plutonium activities and, perhaps with China—which must also share misgivings about a Japanese nuclear weapon option—they might encourage Japan to further slow its plutonium activities. Since Israel's security interests require that the use of plutonium not spread to any of its neighbors, it might be willing to enter into a regional agreement that prohibits the production of weapon-usable material for any purposes.

- **As the number of holdouts is reduced, press harder on the remaining plutonium advocates.** The obstacles to the next steps in fissile material control will progressively weaken as converts are won. The key is for the United States and a growing number of others to formulate goals for the effort and to use their influence to move yet other governments toward those goals.
- **Initiate international efforts to improve the alternatives to plutonium use, including fuel-efficiency improvements in existing and advanced once-through low-enriched or natural uranium-based nuclear reactors,¹⁵ and to identify additional uranium resources at current and higher prices.** Analytical work along this line was conducted in the late 1970s, weakening the economic and resource-efficiency arguments for plutonium. Because the case against plutonium has strengthened in the intervening 15 years, a resumption of this analysis will strengthen the case for fissile material control.
- **Suggest the stockpiling of natural and low-enriched uranium fuel as a more immediate and proliferation-resistant energy security measure than plutonium fuel cycles.** Such stockpiles would protect against short-term uranium supply interruption. They would also protect against long-term uranium price increases by lessening the effect of such increases and by providing time to develop alternative energy sources. This time will be further increased if improved fuel-efficient once-through

¹⁵The advanced once-through uranium-based reactors to be considered for development should include those using uranium-238 and/or thorium-232 as fertile material.

reactors have already been developed and put into use. The large amounts of uranium becoming available from blended-down weapon uranium from the United States and Russia would help to create these stockpiles and their formation would have the added advantage of helping to prevent this excess uranium from disrupting the uranium markets.

- **Suggest no new construction of plutonium facilities,¹⁶ then no new contracts for existing facilities, and finally a phaseout of existing programs.** Much of the political opposition to abandoning plutonium fuel cycles is inspired by the few large organizations that stand to incur capital losses if their activities are terminated early. Many of these capital losses can be minimized by cutting off future investments and contracts for plutonium use and setting the phaseout of existing facilities at a future date—allowing an orderly transition to a phaseout.
- **Explore the financial losses to the operators of existing plutonium programs, the financial gains to ministries and utilities, and the possibility of gainers compensating losers if these programs are terminated.** Reprocessors and the organizations paid to construct plutonium facilities stand to lose profits if plutonium fuel cycles are abandoned. Taxpayers and electric utilities stand to gain savings. After designing programs to phase out plutonium in a manner that minimizes capital losses (see above), the gainers could minimize any residual political opposition by partially or completely compensating the losers. This could be done by a cash transfer (sometimes called “transition assistance”) or by contracts for useful nonplutonium activities such as advanced once-through nuclear reactors or long-term storage of spent fuel, high-level radioactive waste, or existing inventories of fissile materials slated for disposition.¹⁷
- **Realize that the cutoff of production of weapon-usable material for civilian use will not immediately close down the programs**

¹⁶If the cutoff date is set to the recent past, say, 1994, countries cannot rush to their construction to beat the deadline.

¹⁷British Nuclear Fuels, Ltd., the United Kingdom’s reprocessing organization, is now offering storage services in addition to reprocessing. See Haig Simonian, “Business Worries Cloud Prospects for Nuclear Reprocessing Complex,” *Financial Times*, January 23, 1995.

using such material, because existing stockpiles are likely to be adequate for decades. Plutonium and HEU research and use can be conducted for a very long time in the absence of plutonium and HEU production. We do not recommend the long-term continuation of the civilian use of weapon-usable material. However, the logic of the situation permits a sequential approach to shutting down such civilian activities—with a total production cutoff coming first.

- **Look at the possibility of an initial moratorium on the production of weapon-usable material for any purpose, with reviews every 10–20 years to determine whether the case for HEU for naval reactors or the economics of plutonium fuel cycles justifies a reconsideration.** Carrying the sequential approach (discussed above) a step further, it is possible to start with a reversible cutoff of all production. To the extent that the long-term continuation of such a cutoff depends on the future resolution of technical and economic issues—e.g., the satisfactory design of LEU-fueled naval reactors and the continued availability of relatively low-cost uranium—this approach allows future information to be factored into future decisions.

A DISCRIMINATORY OPTION

An alternative to a total cutoff and global stockpile disposition is to allow only a few countries to maintain plutonium activities within their territories. The restriction does not greatly affect the unfavorable economics of plutonium. But—if the “few countries” are reliable, and especially if they are nuclear-weapon states—such a step would reduce the proliferation risks.

Whether such a scheme is more acceptable than a total cutoff depends on two opposing factors. On the one hand, the restriction would be discriminatory. This factor would make the agreement less palatable to some of those countries not selected. Indeed, for many years this issue has been the political roadblock to securing international agreement on such schemes, and even now the Non-Aligned

Movement is calling for access to reprocessing.¹⁸ On the other hand, such a scheme would be more acceptable than a total cutoff to the advocates of plutonium use in those countries that are selected. It might also be acceptable to some of those not chosen, if the agreement allows unselected countries that are willing to forgo plutonium activities to share the benefit of low-enriched and natural uranium freed up by the plutonium programs.

In any case, subnational diversion and national seizure in those selected countries would remain potential problems. Declared nuclear-weapon states would be preferred as the selected countries, because national seizure, if it happened, would do relatively less harm. As to subnational diversion, effectively protecting commercial plutonium, even in nuclear-weapon states, would still be a difficult task.

In sum, the restriction in this scheme makes the treaty discriminatory. The restriction neither improves plutonium economics nor eliminates the risk of subnational diversion. If plutonium activities are allowed only in nuclear-weapon states, the risk of national seizure is significantly reduced.

Similar discriminatory schemes can be developed for dealing with stockpiles. Sensitive material moved to reliable states, preferably nuclear-weapon states, would present less of a proliferation risk. But the risk would still be present. And the discriminatory aspects of the arrangement would be a political roadblock.

Any proposals for dealing with the problem of weapon-usable materials will need to deal with these elements. Flows of materials must be cut off everywhere or restricted in a discriminatory manner. After, or at the same time as, flows are cut off, stocks must be disposed of—either by being reduced or by being transferred to a few well-chosen sites.¹⁹ If the discriminatory route is chosen, the UN General

¹⁸Mark Hibbs, "Last NPT Prepcorn Moves Toward Limited Extension," *Nucleonics Week*, February 2, 1995, p. 9.

¹⁹In the late 1970s an international study explored alternative nuclear fuel cycles with respect to economics and proliferation resistance. While there were many candidates, the only fuel cycles widely agreed to be economical and proliferation resistant were those that depended on low-enriched or natural uranium used on a "once-through"

Assembly's insistence on a "nondiscriminatory" approach in the current proposed convention will have to be relaxed in dealing with civilian uses of plutonium.

ELEMENTS OF A COMPREHENSIVE APPROACH

Whether or not the international community accepts discriminatory regimes, it will need to address the production and stocks of weapon-usable material that are both military and civilian, safeguarded and unsafeguarded, if it is to confront the major technical component of nuclear proliferation. To address this matter, it would be useful to consider negotiating three elements: (1) the U.S.-proposed convention, (2) disposition of existing stockpiles, and (3) a total cutoff or restricted siting of production—simultaneously or in a series of "next steps" planned as a whole.

If a simultaneous negotiation were chosen and it took three years longer than the hypothesized seven-year negotiation of the U.S.-proposed convention to bring all three elements into initial effect, then under the illustrative scenario that effect would come in 10 years as opposed to 21 years. That is, the world would start to reduce the latent and breakout capabilities shown in Figures 1, 2, and 3 in a decade rather than in two decades or more. The simultaneous negotiation could fail, and the world community would have lost three years in the process. However, whatever failed in the simultaneous negotiation could fail in the 21-year sequential approach as well.

The dynamics of the Conference on Disarmament discussions might offer a way to deal with this issue. Ambassador Shannon has assured the Conference that, under the mandate to negotiate a cutoff treaty, the question of existing stockpiles can be discussed. But a fuller production cutoff could also be raised in these discussions and kept on the table.

basis, on discriminatory arrangements, or on both (*International Nuclear Fuel Cycle Evaluation*, International Atomic Energy Agency, Vienna, 1980).

While the U.S.-proposed treaty for a fissile production cutoff for nuclear weapons would not cap the number of potential nuclear weapons available on short notice—days or weeks—it can be used as the first step toward such a cap or even toward a reduction of the threat.

Even as an isolated measure the U.S.-proposed treaty would have two desirable effects. First, the political commitment to peaceful uses of material placed under safeguards has some value for the small number of nations that honor their commitments but are unlikely to join NPT as nonnuclear-weapon states. Israel might be the best example, but it is not clear that Israel would join a treaty when the treaty permits its neighbors to produce weapon-usable material even if such production were under safeguards. Pakistan and India are other possibilities. As to nuclear-weapon states, the United States and Russia, for example, have already agreed to terminate the production of weapon-usable material for nuclear weapons. The convention will formalize the commitment. It would be of some benefit to have China join the proposed treaty although this may not affect its nuclear modernization program. Second, the closing of the NPT Article II loophole so that nonnuclear-weapon states, in addition to nuclear-weapon states, would agree not to aid other nations in “proscribed activities” has some marginal value, mainly in further legitimizing international interdiction measures against such aid.

The interest of some nations in transfers of existing stockpiles to safeguards is a roadblock to agreeing even on the U.S.-proposed treaty. It may be necessary to reach some accommodation on the is-

sue before agreement on a treaty can be reached. This does not mean the total elimination of strategic nuclear stockpiles in nuclear-weapon states, but a "nondiscriminatory" accommodation would affect those stockpiles. Indeed, the United States has offered to put some of its fissile material under safeguards, but this is not the same as a multilateral convention on the subject. No matter how the question of existing stockpiles is handled, the safeguarding of such stockpiles will not reduce the potential number of nuclear weapons available on short notice. Only a reduction of stocks or their removal from unreliable control can do that. The safeguarding of existing stocks—aside from the political commitment it represents—is most valuable as a step toward further measures of fissile material control.

In conjunction with stockpile reduction or transfer of custody, the measure with a significant effect on the number of potential nuclear weapons is a cutoff of weapon-usable material production for all purposes. The United States has advocated restrictions on such production in "regions of instability," but Japan's plutonium program involves the global transportation of arsenal quantities of weapon-usable material with the attendant risk of theft. Moreover, the United States has agreed that the proposed convention is to be "nondiscriminatory"—making it difficult to enhance the treaty with less-than-universal measures.

Consistent with President Clinton's intention to pursue a "comprehensive approach to the growing accumulation of fissile material," the U.S. proposal should not foreclose, significantly delay, or even deemphasize other nuclear nonproliferation measures. These include

- regional approaches,
- military and civilian stockpile dispositions, and
- a total cutoff of weapon-usable fissile material production for civilian and military purposes, or a severely controlled plutonium management scheme that goes far beyond safeguards.

The United States should declare that the objective of the current or subsequent efforts should include (1) the total cutoff or strict control of weapon-usable fissile material production and (2) the reduction or transfer of custody of both military and civilian stockpiles of weapon-

usable fissile material. Before a fissile cutoff treaty—taken in isolation—can be interpreted as an indefinite entitlement to produce weapon-usable material, the United States should start advocating the measures recommended here that will weaken the opposition to banning plutonium and will supplement the cutoff proposal. The cutoff proposal is the first step. It opens the door to more enduring nonproliferation objectives.

**ESTIMATES OF THIRD WORLD COUNTRIES'
INVENTORIES AND ABILITY TO PRODUCE
WEAPON-USABLE MATERIAL**

Various Third World countries may be attempting to develop nuclear weapons. Table 1 showed the amounts of fissile material that each of these countries is estimated to possess. This is the fissile material that could be readily turned into nuclear weapons. This fissile material is either plutonium, which has been separated from spent fuel, or stocks of HEU. The table also shows the current or near-term future capacity of these countries to produce additional amounts of fissile material. This production capacity reflects either spent fuel reprocessing plants or uranium enrichment plants.

Table 1 shows three categories of countries. The first four countries (India, Pakistan, Israel, and North Korea) are undeclared nuclear-weapon states. The next three countries (South Africa, Brazil, and Argentina) have facilities that could be used to produce weapon-grade fissile material but the current political condition in these countries is such that they are not trying to produce nuclear weapons. It is interesting to note that in these three countries, these facilities were originally developed to support nuclear-weapon programs. The last five countries (Iraq, Iran, Syria, Algeria, and Libya) are believed to be interested in acquiring nuclear weapons but have not been able to obtain the fissile material required.

INDIA

India's main source of plutonium is its two research reactors, Cirus and Dhruva. Cirus, which produces about 9 kg of plutonium per year, has been in operation since 1960. Dhruva, which produces

about 22.5 kg of plutonium per year, has been in sustained full power operation since 1988. Both of these reactors use natural uranium fuel in metallic form. The metallic uranium spent fuel is hard to store in water for more than about five years because of corrosion problems.¹ Therefore, it is likely that most of the older spent fuel from these reactors has been reprocessed. During the 1960s and early 1970s, this fuel was reprocessed in the plant at Trombay. Since 1976, the reprocessing has been performed in the plant at Tarapur. At the end of 1994, these two reactors would have produced about 475 kg of plutonium. Making allowance for plutonium that is in partially burned-up fuel still in the reactors and assuming that the last two years' output of spent fuel has not yet been reprocessed (to allow time for the radioactivity of the spent fuel to decline), about 405 kg of plutonium would actually have been separated from these two reactors' spent fuel. Because of the low burnup of the research reactor fuel, this plutonium is weapon-grade.

India also has nine power reactors in operation that have discharged spent fuel containing over 4,500 kg of plutonium. However, it is thought that very little of this spent fuel has been reprocessed. The lack of reprocessing is thought to result from the fact that the only two reactors near the Tarapur reprocessing plant are U.S. supplied, and the United States has refused India permission to reprocess the fuel. The other seven reactors are not close to the Tarapur reprocessing plant, and the logistical difficulties in transporting the spent fuel to Tarapur have limited the amount of power reactor spent fuel that has been reprocessed. Currently, only about 100 kg of plutonium is thought to have been recovered from the power reactor fuel.² All of this material is probably reactor-grade.

India does have a reprocessing plant under construction at Kalpakkam. This plant is thought to be almost complete. Two of India's unsafeguarded power reactors (Madras 1 and 2) are at this site. When the reprocessing plant is completed, India may start to reprocess much more of its spent power reactor fuel.

¹Statement by P. K. Iyengar, director of India's Department of Atomic Energy. See Mark Hibbs, "Dhruva Operating Smoothly Within Refueling, Availability Limits," *Nucleonics Week*, March 26, 1992, p. 9.

²Mark Hibbs, "Indian Pu Production Overstated, No Pit Production, Iyengar Says," *Nucleonics Week*, April 9, 1992, p. 6.

India has used some of its separated plutonium for its small breeder reactor program as well as for its nuclear explosion in 1974. All of this plutonium was probably weapon-grade. Assuming that this material amounts to about 50 kg, India's current stockpile of plutonium is about 450 kg, of which 350 kg is weapon-grade.

Regarding future plutonium production, India will at a minimum keep reprocessing the spent fuel from the two research reactors. This will produce just over 30 kg of weapon-grade plutonium each year. If the reprocessing plant at Kalpakkam is completed and it and the reprocessing plant at Tarapur are used to reprocess spent power reactor fuel, India could produce up to 700 kg of plutonium each year. This would be reactor-grade plutonium. However, it should be noted that India's five unsafeguarded power reactors are totally under its control and India could operate these reactors so as to produce some additional weapon-grade plutonium. Not all of the power reactor plutonium could be produced as weapon-grade, but it would not be hard for India to increase its weapon-grade plutonium production to 100 kg per year.

India is able to produce HEU in addition to plutonium. Since 1985, India has had a small centrifuge enrichment plant in operation at the Bhabha Atomic Research Center. A somewhat larger plant was opened near the city of Mysore around 1990. The capacity of these plants is not known, but it is probably around 1,000 separative work units (SWU) per year. The short equilibrium time associated with the centrifuge process means that even if these plants are not configured to produce HEU, they could be used to produce HEU by a batch recycling process. It is not known if India has done this, but it would have been easy for India to have produced roughly 10 kg of HEU from the past operation of these enrichment plants. If used in an all-out effort to produce HEU, these plants could in the future produce 10 kg of HEU per year.

Though not shown in the table, India is known to have produced U-233, which is another material that can be used to make nuclear weapons. This U-233 has been produced by the irradiation of thorium in India's research and power reactors. India has likely already produced and separated a few kilograms of U-233 and if it wanted to it could continue to produce a kilogram or two of U-233 each year.

PAKISTAN

Pakistan has a centrifuge enrichment plant at Kahuta, which is thought to have a capacity of around 5,000 SWU per year. The plant is thought to have produced HEU from the mid-1980s to the early 1990s, when the plant was shut down as a result of U.S. pressure. The plant could have produced about 25 kg of HEU per year during this time, so Pakistan's current HEU stockpile is likely to be about 200 kg. The plant is currently not thought to be operating; but, if it were restarted, it could continue to produce 25 kg of HEU per year.

ISRAEL

Israel has a plutonium production reactor at Dimona that has been in operation since 1964. The amount of plutonium that this reactor has produced depends on the reactor's power level. It has been reported that the reactor was originally designed by the French (who provided the reactor to Israel) to have a power output of 24 MW.³ There are also reports that the Israelis have increased the reactor's power so as to increase its rate of plutonium production. Some reports place the reactor's power at 150 MW. We consider it unlikely that a reactor that was originally designed to have a power output of only 24 MW would be upgraded to 150 MW, since such an upgrade would require significant changes in the fuel element design and in the design of the refueling system. We consider more likely reports that the reactor's initial power level was 40 MW and that its power level was increased to 70 MW in the mid-1970s.⁴ For our calculation, we assume that the reactor operated at 40 MW from the beginning of 1965 to the end of 1975 and since then has operated at 70 MW. By the end of 1994, the reactor would have produced about 400 kg of plutonium. Subtracting the plutonium that is still in the reactor in partially burned up spent fuel and plutonium in the last several years of spent fuel discharges that probably have not been reprocessed yet would leave Israel with a current stockpile of about 350 kg of plutonium. All of this plutonium would be weapon-grade. The reactor will continue to produce plutonium at a rate of about 16 kg per year.

³All megawatts in this appendix are thermal MWs, as opposed to electric MWs.

⁴Leonard S. Spector, *Nuclear Ambitions*, Westview Press, Boulder, Colorado, 1990, p. 160.

NORTH KOREA

North Korea has a 25 MW plutonium production reactor, which has been in operation since 1987. This reactor has been under IAEA safeguards since early 1992, and since that time fuel has been removed only once—in 1994. The fuel recovered in 1994 has not been reprocessed; as part of the October 21, 1994, U.S.-DPRK Agreed Framework, North Korea has agreed not to reprocess it in North Korea. The key question is how much plutonium North Korea recovered from this reactor before 1992. The North Koreans claim that they did not recover any significant amounts of plutonium before 1992, but there is evidence that they have lied. The IAEA intended to answer this question definitively by analyzing the fission product concentrations of the various spent fuel elements recovered in 1994, but North Korea would not allow the IAEA access to the fuel during its removal and has so jumbled the spent fuel that such an analysis is no longer possible. Another way to answer this question definitively is to inspect two sites where the waste produced by the reprocessing of fuel recovered before 1992 is believed to be stored. The IAEA attempted to carry out an inspection in early 1993, but North Korea refused to allow it and threatened to withdraw from the NPT. The U.S.-DPRK Agreed Framework has postponed the inspection of these two sites for another five years.

If the reactor were run in a manner similar to other plutonium production reactors, it is likely to have been refueled in 1989, 1990, and 1991. Plutonium traces recovered from North Korean equipment by the IAEA indicate that plutonium was reprocessed in each of those years. Run in this fashion, the North Koreans could have separated 20–30 kg of plutonium before 1992. All of this plutonium would be weapon-grade.

Curiously, the U.S. government believes that the reactor was refueled only once before 1992—in 1989. Why the U.S. government believes this is unclear, since this would imply that the North Koreans operated their reactor in a suboptimal way and this is contradicted by the plutonium trace evidence.⁵ The U.S. government believes that with

⁵Our case is further strengthened by statements made by high-ranking South Korean government officials who said that U.S. intelligence has detected three prolonged shutdowns of the North Korean reactor, during which time it could have been

this single refueling, North Korea's current plutonium stockpile is less than 10 kg.⁶

Under the U.S.-DPRK Agreed Framework, North Korea has pledged not to operate the 25 MW reactor or the 200 MW and 800 MW reactors, the construction of which has almost been completed. If North Korea abides by its pledge, then it will not add to its separated plutonium stockpile in the near term.⁷ But if North Korea violates the agreement, then it could start to produce 250 kg of plutonium per year, all of which would be weapon-grade.

SOUTH AFRICA

In the late 1960s, South Africa began research on enrichment technology. By the early 1970s, the research was far enough advanced for work to begin on a pilot plant, which was known as the "Y-plant." The technology in this plant was unique. It was termed "advanced vortex tube." It is an aerodynamic process in the same family as the German Becker Nozzle process. In 1974, South Africa decided to build nuclear weapons. In 1978, the Y-plant began to produce HEU in support of the South African nuclear-weapon program. By 1990, the plant was shut down and then dismantled. By this time, enough HEU had been produced to build six gun-type nuclear weapons.

In 1989, South Africa decided to terminate its nuclear-weapon program. By 1991, the last weapon was dismantled, and South Africa joined the NPT. In dismantling the nuclear weapons, the HEU metal was recast, but it is still stored in South Africa.

refueled. One occurred for 71 days in 1989, one occurred for "30-odd" days in 1990, and one occurred for "50-odd" days in 1991. See *JPRS Report—Proliferation Issues*, Foreign Broadcast Information Service, JPRS-TND-94-016, August 19, 1994, p. 2.

⁶Testimony of Robert L. Gallucci, Ambassador At-Large, *On the Agreed Framework with North Korea*, Before the Senate Foreign Relations Committee, Subcommittee on East Asian and Pacific Affairs, December 1, 1994.

⁷A possible exception is the roughly 20 kg of plutonium contained in the spent fuel that was recovered during the 1994 refueling of the 25 MW reactor. The U.S.-DPRK Agreed Framework does not permit this spent fuel to be reprocessed in North Korea. However, there is nothing in the Agreed Framework to prevent the fuel from being reprocessed in, say, China, and the plutonium so recovered from being sent back to North Korea.

The South Africans have not revealed the size of their current HEU stockpile. The Y-plant appears to have had a capacity of about 10,000 SWU per year. One reasonable estimate of the South African HEU stockpile is 700–800 kg.⁸ Because the Y-plant has been dismantled, it cannot be used to produce HEU in the future. Indeed, even if the Y-plant still existed, the current political climate in South Africa is such that it is unlikely that any HEU would be produced. However, South Africa has another enrichment plant—the Z-plant. This plant has been in operation since 1988 and is also based on the advanced vortex tube technology. It has the capacity to produce 300,000 SWU per year. It is being used to produce LEU to fuel South Africa's power reactors. The equilibrium time of this advanced vortex tube process is short enough that it could be operated in a batch mode to produce HEU. If it were used in this way, it could produce about 1,000 kg of HEU per year.

BRAZIL

The Brazilian Navy began work on centrifuge enrichment in 1979. By 1988, it was reported to have had 50 machines in operation. By 1990 and 1991, about 500 machines were in operation with a capacity of about 1,700 SWU per year. Brazil planned to increase the number of machines to 5,000, but it is thought that budget constraints prevented this from happening.

This enrichment effort is intended to produce 20 percent enriched uranium to support the Brazilian Navy's nuclear submarine development. Since 1990, these 500 centrifuges could have produced about 200 kg of 20 percent enriched uranium. In the future, however, if there were a political change, there could be a desire to produce HEU. As in the case of India, the short equilibrium time of the centrifuge process allows HEU to be easily produced by batch recycling. If this were done, the 500 centrifuges could produce about 10 kg of HEU per year. If the expansion to 5,000 centrifuges were to take place, about 100 kg of HEU could be produced per year.

⁸Thomas B. Cochran, "Highly Enriched Uranium Production for South African Nuclear Weapons," *Science & Global Security*, Vol. 4, 1994, pp. 161–176.

ARGENTINA

In 1983 Argentina surprised the world with the announcement that it had built a gaseous diffusion plant. The plant was supposed to have a capacity of 20,000 SWU per year and to produce 20 percent enriched uranium for use in research reactors and perhaps an eventual naval reactor program. At this capacity, the plant could produce 500 kg of 20 percent enriched uranium per year. However, the plant has not operated well; indeed, Argentina would have little use for so much 20 percent enriched uranium each year.⁹ It is hard to estimate Argentina's current stockpile of 20 percent enriched uranium, but plausibly it could be anywhere from zero to 500 kg.

Unlike the centrifuge and aerodynamic enrichment processes, the equilibrium time of the gaseous diffusion process is too long to permit the production of HEU by batch recycling. However, since the plant is already designed to produce 20 percent enriched uranium, it would not be too difficult for Argentina to extend the plant's output to 90 percent enrichment. This would require a large number of additional stages, but the stages would be small because the cascade flow is not large in the upper part of the cascade. If this extension were done and the plant operated to capacity, it could produce about 100 kg of HEU per year.

IRAQ

In the aftermath of the 1991 Gulf War, it was discovered that Iraq had an active nuclear-weapons program. Iraq had parallel programs to acquire HEU using both centrifuge and electromagnetic isotope separation. Neither of these programs had managed to produce any significant amount of HEU before the war started. The programs have been stopped and all known equipment destroyed. Any research reactor fuel containing HEU has been removed from Iraq. Nevertheless, it is likely that once UN inspections and sanctions end, Iraq will again try to obtain either plutonium or HEU for nuclear weapons.

⁹David Albright, Frans Berkhout, and William Walker, *World Inventory of Plutonium and Highly Enriched Uranium 1992*, Stockholm International Peace Research Institute, Oxford University Press, 1993, p. 180.

IRAN

Iran is believed by the Central Intelligence Agency (CIA) to have a nuclear-weapons program. As of early 1994, the CIA estimated that Iran could have a nuclear weapon within six to eight years.¹⁰ Iran, though it has purchased some power reactors and various research equipment, has not yet been able to acquire the facilities that would permit it to produce either separated plutonium or HEU. There is a concern that, given the conditions in Russia, Iran might be able to obtain plutonium or HEU directly.

SYRIA, ALGERIA, AND LIBYA

Syria, Algeria, and Libya are all thought to be interested in acquiring nuclear weapons, but thus far none of these countries has been able to obtain the plutonium or HEU required.

¹⁰Statement by CIA spokesperson, Dave Christian, on February 16, 1994. See Philip Finnegan and Theresa Hitchens, "U.S. Fights Dual-Use Technology Flow to Iran," *Defense News*, February 28–March 6, 1994, p. 6.